Nature Conservation 59: 157–177 (2025)
DOI: 10.3897/natureconservation.59.145873

Research Article

Successful translocation of the Transylvanian Bavius Blue - *Pseudophilotes bavius hungarica* (Diószeghy, 1913) (Lepidoptera, Lycaenidae) in Romania, for increased protection and conservation

Răzvan Popa[1,2], László Rákosy[3,4,5], Andrei Crișan[3], Florin-Mihai Pop[2,3], Demetra Rákosy[6]

1 *Fundatia ADEPT Transylvania, Str. Principală 166, 547510 Saschiz (Mureș), Romania*
2 *Doctoral School of Integrative Biology, Faculty of Biology and Geology, Babeș-Bolyai University, Str. Republicii 44, 400015 Cluj-Napoca, Romania*
3 *Romanian Lepidopterological Society, Str. Republicii 48, 400015 Cluj-Napoca, Romania*
4 *Department of Taxonomy and Ecology, Babeș-Bolyai University, Str. Republicii 48, 400015 Cluj-Napoca, Romania*
5 *Department of Forestry and Environmental Protection, Ştefan cel Mare University, Str. Universităţii 13, 720225 Suceava, Romania*
6 *Thünen Institute for Biodiversity, Bundesallee 65, 38116 Braunschweig, Germany*
Corresponding authors: László Rákosy (laszlo.rakosy@ubbcluj.ro); Demetra Rákosy (demetra.rakosy@thuenen.de)

OPEN ACCESS

Academic editor: Romain Julliard
Received: 9 January 2025
Accepted: 4 May 2025
Published: 11 August 2025

ZooBank: https://zoobank.org/6677BEE5-93D9-486B-A064-DDF4961708DC

Citation: Popa R, Rákosy L, Crișan A, Pop F-M, Rákosy D (2025) Successful translocation of the Transylvanian Bavius Blue - *Pseudophilotes bavius hungarica* (Diószeghy, 1913) (Lepidoptera, Lycaenidae) in Romania, for increased protection and conservation. Nature Conservation 59: 157–177. https://doi.org/10.3897/natureconservation.59.145873

Copyright: © Răzvan Popa et al.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Abstract

Pseudophilotes bavius is a butterfly species protected by the EU Habitats Directive. The subspecies *P. bavius hungarica*, known by the vernacular name Transylvanian Blue, is endemic to the Transylvanian Plain (Transylvanian Plateau) in Romania. Its distribution is limited to dry grasslands on steep, south-facing slopes, always in association with *Salvia nutans*. Unfortunately, many of the extant populations of *P. bavius hungarica* are threatened with extinction due to overgrazing by sheep, abandonment of grasslands and afforestation. In order to safeguard this emblematic species, an attempt was made to colonise another suitable habitat patch over 100 km away from the donor sites. Only one year after the translocation of 11 females, a viable core population was formed. In order to strengthen the core population, in 2024, a further six females were translocated. The newly-formed population will increase the resilience of the subspecies and shows a way forward in protecting highly localised, endemic taxa in Romania. The creation of a nature reserve with special protection and conservation measures in the translocation area and the commitment of local stakeholders will ensure the maintenance of the Transylvanian Blue in Romania.

Key words: Conservation, endangered, endemic, Lepidoptera, Lycaenidae, protected species, *Pseudophilotes bavius hungarica*, Romania, translocation, Transylvania

Introduction

An avalanche of reports has drawn attention to declines in insect abundance, biomass, species richness and range sizes (Van Dyck et al. 2009; Hallmann et al. 2017, 2021; Forister et al. 2019; Van Klink et al. 2020, 2024; Wagner 2020; Wagner et al. 2021). It is, however, still not clear whether these trends are universal or dependent on the geographic region, habitat, degree of human population density or other species-specific factors (Wagner 2012; Habel et al. 2019a;

Seibold et al. 2019; Wagner et al. 2021; Van Klink et al. 2024). Butterflies are amongst the species groups which have been most often used to assess the impact of global change. Butterflies have been shown to be particularly good indicators, as their short life cycles, close association with special habitats and/or food plants, often limited dispersal ability and other characteristics makes them sensitive to shifts in land-use and climate (Settele et al. 2008; Van Swaay and Warren 2012; Halsch et al. 2021; McCain and Garfinkel 2021; Warren et al. 2021). They are also relatively easy to observe and identify, which makes them ideal candidates for monitoring initiatives (Van Swaay et al. 2008).

Multiple studies, as well as monitoring data, show that butterfly populations are declining worldwide, largely due to the loss, degradation and fragmentation of their habitats (Van Swaay and Warren 2006; Warren et al. 2021; Mora et al. 2023), but also due to climatic changes that cause shifts in community structure and induce often inappropriate phenological adaptations (Diamond et al. 2011; Devictor et al. 2012; Costache et al. 2021). In Europe, 39% of grassland butterflies are in decline (Warren et al. 2021). With recent studies showing that the decline of widely distributed generalist species is less pronounced than that of specialised, isolated species (Habel et al. 2012, 2019b). Specialised species that are unable to move long distances are particularly susceptible to suffering from habitat loss and fragmentation of meta-populations (Thomas et al. 2001).

As the decline of butterflies is progressing at an increasing rate, conservation measures have expanded their focus beyond maintaining and restoring habitats (Warren and Bourn 2011), with increasing efforts to compensate for the losses through translocation or re-introduction of threatened butterfly species to new or former sites (Thomas et al. 2011; Merckx et al. 2013). Although, in the past, re-introductions have had a generally low success rate (Bubac et al. 2019), the results of the last 10–15 years are much more optimistic. Thus, in the last 10 years, translocation or re-introduction attempts have increased in number, but also in efficiency, most likely due to the accumulation of experience and the use of more elaborate protocols aimed at maintaining genetic diversity (Joyce and Pullin 2003). Successful cases of insect re-introductions, such as the Large Blue (*Phengaris arion*), the Chequered Skipper (*Carterocephalus palaemon*) or the False Ringlet (*Coenonympha oedippus*) demonstrate the potential of insect re-introduction programmes (Thomas et al. 2009; Ellis et al. 2011; Andersen et al. 2014; Wildman 2023; Čelik et al. 2024).

Such success stories provide incentives to assess the potential of translocation for the conservation of other butterfly species, in particular, those with high degree of specialisation and restricted occurrences. *Pseudophilotes bavius* (Lycaenidae), may be an ideal candidate for such conservation measures. It is included in the annexes II and IV of the EU Council Directive 93/43/EEC1 on the conservation of natural habitats and wild fauna and flora. However, in the European Red List of Butterflies (Van Swaay et al. 2010), *P. bavius* is considered only Least Concern. Maes et al. (2019) raise the degree of endangerment to Vulnerable. *P. bavius* is also protected by Romanian legislation (OUG no. 57/2007, approved with amendments by Law 49/2011), in seven Natura 2000 sites.

Two subspecies of *P. bavius* occur in Romania: ssp. *bavius* (Eversmann, 1832) in the steppe and silvosteppe of Dobrogea (S-E Romania) and ssp. *hungarica* (Diószeghy, 1913) in Transylvania (Rákosy and Weidlich 2017).

Figure 1. *P. bavius hungarica* **A** male **B** female. Photo credits: László Rákosy.

P. bavius hungarica with the vernacular name "Transylvanian Bavius Blue" (Fig. 1A, B) is a protected endemic butterfly subspecies threatened by habitat degradation, changing agricultural practices leading to overgrazing and abandonment of traditional activities or afforestation (Crișan et al. 2011, 2014, 2023; Dincă et al. 2011; Német et al. 2016; Rákosy and Weidlich 2017; Rákosy et al. 2021). The biology and ecology of *P. bavius hungarica* have been the subject of recent articles (Crișan et al. 2011, 2014, 2023; Dincă et al. 2011; Német et al. 2016; Rákosy and Weidlich 2017; Rákosy et al. 2021). Its north-easternmost distribution site was discovered recently (Balan et al. 2020).

The distribution area of the *P. bavius hungarica* is limited to the steppe-like habitats of the Transylvanian lowlands, where the food plant of the caterpillars, *Salvia nutans* (Nodding Sage), occurs (Fig. 2). The insular occurrence of *S. nutans* is much larger in comparison to the few, punctiform, known populations and colonies of *P. bavius hungarica* (Fig. 2). The distribution map of *S. nutans* was compiled on the basis of our field observations, botanical publications (Schneider 1996; Oroian et al. 2017) and herbarium specimens. Many of the known populations or colonies of *P. bavius hungarica* have become extinct or have been threatened with extinction in the last hundred years, but especially after 1980. Currently, the status of many of the extant populations is critical. However, the fact that suitable habitats occur beyond the species current occurrence points raises the opportunity for the creation of new viable populations. In the present study, we describe the first successful attempt to translocate *P. bavius hungarica* to a new location, with the aim of creating a refuge site for the species.

Methodology

General motivation

Species translocations are challenging and should be conducted with a deep understanding of the species ecology, habitat requirements and distribution (Osborne and Seddon 2012). We have a long experience in studying *P. bavius hungarica*, assessing and documenting the species and its distribution in Transylvania, its biology and ecology since 1977 (König 1992; Jutzeler et al. 1997; Crișan et al. 2011). Considering the intensity of the threats to its population, conservation measures are imperative. We test the usefulness

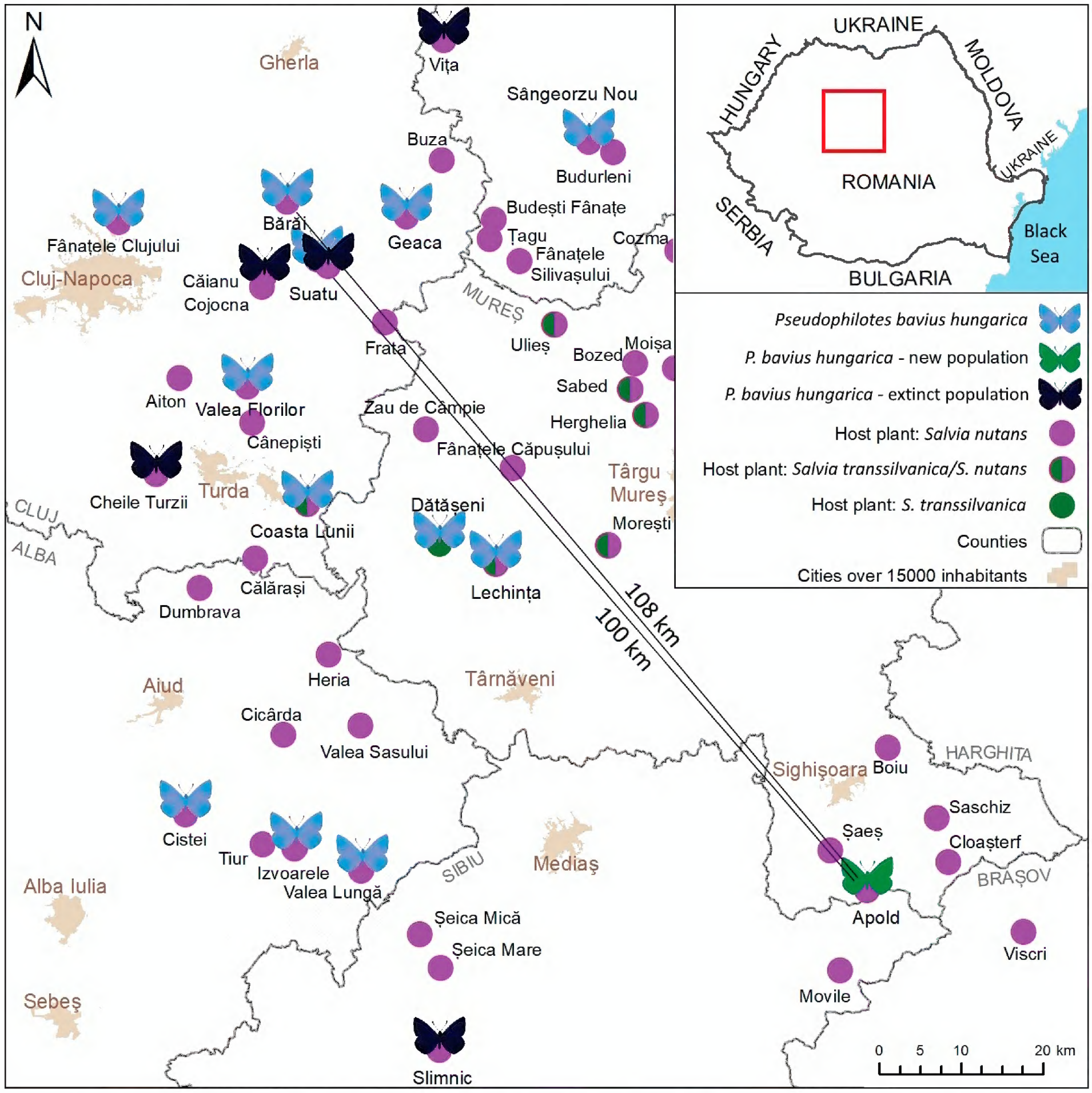

Figure 2. Distribution map of *P. bavius hungarica* and *S. nutans* in the Transylvania, indicating the sources of female translocation sampling and distances to the translocation site.

of translocations for ensuring the survival of *P. bavius hungarica*. Translocations appear a suitable tool for this species, considering its high specialisation and short activity period, characteristics which would also minimise any impact it could have on the biological communities at its introduction sites. Furthermore, suitable habitats are available beyond the species current distribution (Fig. 2). The translocation attempt has been conducted within the framework of the LIFE project "Metamorphosis" (https://fundatia-adept.org/life-metamorphosis). One of the key objectives of this project is the introduction or re-introduction of endangered species. After obtaining the necessary agreement from the Romanian Academy, Commission of Monuments of Nature, a plan for the translocation of *P. bavius hungarica* from Suatu (Cluj County) to Apold (Mureș County) was elaborated.

Selection of the donor site

One of the best-known and strongest populations of *P. bavius hungarica* was located in the botanical reserve from Suatu. The Suatu Nature Reserve was established in 1932 mainly to protect and preserve the endemic *Astragalus peterfii* and other steppe plant species that are rare or very rare in Transylvania. Until 1985, the Suatu Nature Reserve was mowed at the beginning of August, after which 2–3 horses, 3–4 cattle and a few sheep belonging to local residents/inhabitants occasionally grazed the area. In 2000, a project was carried out to develop a management plan for the conservation of biodiversity. The management plan included some inappropriate measures that led to the loss of valuable species and a decline in biodiversity in the nature reserve. The inappropriate measures included: barbed wire fences to prevent domestic animals from grazing, hedges with *Spirea* and *Forsythia*, expansion of the nectar resources by introducing allochthonous species, such as *Buddleja davidii*, a plant of Asian origin with remarkable invasive potential etc., (Mihuț et al. 2001). The abolition of mowing (due to the retirement of the custodian of the protected area) and extensive grazing (by the barbed wire fence) favoured the massive development of competitive grass species (*Brachypodium pinnatum*, *Calamagrostis epigeios*, *Stipa* sp.) to the detriment of valuable, protected species, whose density within the protected area was significantly reduced (Rákosy 2011).

Until 2000, the strongest and most viable population of *P. bavius hungarica* was known in the nature reserve. After 2000, the population of *P. bavius hungarica* declined significantly, while at the same time, the larval host *S. nutans* was reduced. In the period between 2005 and 2010, no further specimens of *P. bavius hungarica* were sighted in the reserve. Fortunately, the population established itself 600 and 700 m further west, on vineyard terraces abandoned between 1960–1965. Here, *S. nutans* found a very favourable habitat on the slopes of the vineyard terraces and *P. bavius hungarica* followed its host plant (Fig. 3).

Since 2011, the abandoned vineyard terraces have been part of a Natura 2000 site and have, thus, been given protected status. Between 1998 and 2010, *P. bavius hungarica* population here was estimated at around 900–1000 specimens (Crișan et al. 2011, 2014). Unfortunately, the status as a Natura 2000 site did not guarantee the protection of the local population, which has been severely damaged by overgrazing with sheep in the last 7–8 years (Fig. 4). Grazing also took place at unfavourable times, during the flowering time of *S. nutans*. Thus, the sheep consumed all flowering *S. nutans* specimens on which eggs and/or larvae of *P. bavius hungarica* were laid between 15 April and 15 May. Despite the destruction of the population, next year individuals of *P. bavius hungarica* settled on a hillside with S-E orientation, about 400–500 m away from the former vineyard terraces, a location from which it was never before recorded (Fig. 5). About 30 to 35 years ago, this slope was intensively grazed by sheep, but after partial afforestation with black and red pines, to protect the pines, grazing was prohibited and the habitat at least partially recovered. In the last 5 years, the strongest population of *P. bavius hungarica* known to us has developed on the non-afforested parts of the slope.

The population of Suatu (outside of botanical reserve) was selected as a source population for three important reasons:

1. With about 150 to 300 specimens estimated population size (on just about 1.5 ha) in the last 3 years, it is by far the most vigorous known population of *P. bavius hungarica*.
2. As the sheep herd grazes only a few hundred metres away, this population could also be very easily exterminated by grazing. Thus, in spring 2023, we collected 11 females (the focus was placed to extract females which appeared to carry eggs) from Suatu to be transferred to the steppic grasslands found on the Apold tumps (small isolated hillocks otherwise known as glimee or slumping hills) (Mureș County).
3. Being outside the nature reserve, the conservation objectives of the protected natural area remain unaffected by the extraction of the individuals.

Selection of the site for translocation

The site for the *P. bavius hungarica* colonisation trial was carefully selected. Species distribution models (SDMs) were used to identify the current and potential species occurrences and to identify areas that could be important for conservation action (Villero et al. 2017; Herrando et al. 2019). SDMs are widely used in the context of species re-introductions (Hunter Ayad et al. 2020; Bellis et al. 2021). We used SDMs for the identification of potential habitats of *P. bavius hungarica* based on the occurrence of the caterpillar feeding plant, microclimatic and

Figure 3. Habitat of the species on the abandoned vineyard terraces of Suatu. Photo credit: László Rákosy.

Figure 4. Habitat on vineyard terraces destroyed by intensive grazing. Photo credit: László Rákosy.

edaphic factors (Crișan 2012). Detailed results of this approach can be found in Crișan (2012). The advantages and disadvantages of the SDMs method have been thoroughly discussed in numerous papers (Maes et al. 2019; Draper et al. 2019; Hunter-Ayad et al. 2020; Halford et al. 2024). However, we made the final decision by taking into consideration both the SDMs (Crișan 2012) and our many years of experience and knowledge of local land-use and management patterns.

Site/Habitat description

The tumps (glimee, slumping hills) are individual or groups of small hills with sloping slopes up to 50 m in height, the inclination of which can be up to 70°, with a mean area of about 1.2 ha. They were formed by the sliding of water-permeable rock masses (sandstone, sandy marl) on an impermeable clay layer base on a more or less inclined slope. The height and dimensions of the individual hills indicate the considerable thickness of the uplifting layers. Pollen analyses place the time of their formation in the final phase of the Würm glacial (Morariu et al. 1964; Fărcaș et al. 2006; Tanțău 2006). The northern slopes are very different from the southern slopes regarding their microclimate. For example, the south-facing slopes are characterised by extremely high temperatures, high insolation, low humidity, high evaporation rates and most distinct continentality, whereas the shaded slopes of northern aspect show the highest

Figure 5. New habitat occupied by *P. bavius hungarica* outside of the botanical reserve, after destruction of the plant on vineyard terraces. Photo credit: Andrei Crișan.

humidity ratios and lowest light and temperature values, as well as the lowest evaporation rates and less distinct continentality. The temperature values on the southern slope were twice as high as those on the northern slope, with an annual average of 18 °C on the southern slope compared to an annual average of 9 °C on the northern slope. These differences can be clearly seen in the arrangement of the plant communities (Schneider 1996; Schneider-Binder 2007).

Amongst the numerous rare plant species, there can be found: *Carex humilis*, *Stipa pulcherrima*, *Salvia nutans*, *Jurinea mollis*, *Artemisia pontica*, *Brassica elongata*, *Cephalaria radiata*, *Centaurea micranthos* and *Koeleria gracilis*, (Schneider-Binder 2007). Lepidopterists have also discovered interesting species of butterflies, such as *Heteropterus morpheus*, *Pyrgus alveus*, *Papilio machaon*, *Iphiclides podalirius*, *Satyrium spini*, *S. pruni*, *S. acaciae*, *Cupido osiris*, *C. decolorata*, *Pseudophilotes vicrama*, *Phengaris arion*, *Kretania sephirus*, *Melitaea phoebe*, *M. aurelia* etc. (personal obs. L. Rákosy).

The southern slopes of the Apold landslide tumps, especially the large one, have a high density of *S. nutans* (Fig. 6). The microclimate is similar to that of the Transylvanian Plain, from which the females captured for resettlement originated. The modelling of climatic and ecological parameters for the next 25 to 50 years shows that the area has great potential for the expansion of the species' range to the south-east. Another important argument was the fact

Figure 6. The Apold tumps on which the translocation of *P. bavius hungarica* was carried out with details on the plant association, dominated by *S. nutans* (right corner). Photo credit: László Rákosy and Andrei Crișan.

that the ADEPT Foundation has acquired the large landslide mound near Apold for nature conservation purposes. This means that targeted management for *P. bavius hungarica* can be carried out and controlled without being dependent on other decision-making factors. In other words: we would have an ideal situation for creating a refuge of *P. bavius hungarica*, by establishing, maintaining and strengthening its population at this site.

Sampling

In April 2023, four entomologists, members of the Romanian Lepidopterological Society, familiar with the biology and ecology of the species, collected 11 females of *P. bavius hungarica* in Suatu and transported them to Apold (Mureș County), where they were released on the slopes of the hills (Fig. 7). The 11 females, six of which were freshly emerged, were placed individually in a plastic box. We collected fresh females in order to minimise the possibility of the females having already laid eggs before the translocation. Proterandry - the emergence of males before females - is well known in *P. bavius hungarica*. As a result, copulation usually takes place right after the females emerge, hence focusing on fresh females does not increase the risk of collecting unmated females for translocation.

The 11 boxes were transported in a larger cool box at 7–8 °C to the large tump near Apold. The approximately 170 km were travelled in 2.5 hours, with the butterflies being released one after the other at the foot of the hill between 12:15 h and 13:00 h. Each of the released specimens settled on *S. nutans* or another plant at a distance of 3–10 m from the release site. Within 10 minutes of release, one female was observed laying an egg on an unopened *S. nutans* inflorescence.

In 2024, we planned to release further individuals of *P. bavius hungarica* in Apold, in order to increase the species establishment chances. As the onset of spring was at least two weeks early in 2024, the collection of further females,

Figure 7. Release of a *P. bavius hungarica* female on the Apold tumps. Photo credits: Răzvan Popa.

originally aimed to be conducted at the peak flight period of the imagines, was conducted in the middle of April (11.04.2024). As expected, we found that both males and females of *P. bavius hungarica* were already in full flight at Suatu. This was the earliest record of the species in the last 30 years. In view of the obvious protandry of the species, we assume that the flight period began 5 to 6 days earlier. Three fresh females were collected to be transported to Apold. To increase the genetic diversity of the Apold core, we travelled to another site with *P. bavius hungarica*, Bărăi, where we collected three more females. The six females were relocated to Apold on the 2nd day.

In order to assess the success of the translocation, a targeted monitoring scheme has been set up, aimed at keeping track of the potential development of the *P. bavius hungarica* population at Apold. This includes a yearly assessment of the population during the peak of its flight period. In 2024, the first assessment was conducted before the new females were released on 12 April. A second assessment was conducted on 23 May, this time aimed at determining whether the females were successful in depositing eggs. These initial assessments were aimed at ensuring that the translocations have been successful, with follow-ups aimed at monitoring the longer-term changes in the population.

Results

On 12 April 2024, we observed the first *P. bavius hungarica*, a female, flying over the *S. nutans* flowers on the slope of the large hill near Apold. This was before the first female of the second translocation batch had been released. In the

next 30 minutes, we counted 17 specimens of *P. bavius hungarica* on the large hill and a neighbouring hill. After confirming the presence of the species after the translocation in 2023, we released the six newly-selected females. During the second assessment on 23 May 2024, we found several larvae of *P. bavius hungarica* on open or partially open inflorescences of *Salvia nutans* (Fig. 8).

With only 11 females *P. bavius hungarica* translocated from Suatu to Apold in 2023, the first nucleus for a new population of this endemic, protected, but endangered taxon was formed. We estimate that the newly-formed nucleus consisted of 30 to 40 individuals, males and females, only one year after the relocation. The large number of larvae found in a short period of time at the end of May 2024 indicates that *P. bavius hungarica* may successfully establish at Apold, creating a protected refugium for this species.

Figure 8. *P. bavius hungarica* larvae (highlighted by the red arrow) found on the Apold tumps in May 2024. Photo credits: László Rákosy.

Discussion

In the present study, we present the results of the first successful translocation of *P. bavius hungarica* in Transylvania. The translocation was made necessary by the increasing threats to the extant populations of this species through inadequate management of its habitat. The newly-selected location for establishing a refugium for this species, not only fulfils all the habitat requirements of the species, but, as it is managed by a conservation focused local stakeholder, also provides a longer-term chance of survival.

Translocations, in particular to locations where the focus species has never occurred, have been somewhat controversial (Bubac et al. 2019). In the following, we discuss some key issues, from the perspective of *P. bavius hungarica*: a) Translocations do not solve the root problem, habitat degradation; b) The genetic makeup of the newly-established population is determined by just a few individuals from two source populations; c) Introducing species to new environments could have unforeseen consequences for local communities; d) While in the short term, the translocation has been successful, long-term survival chances still needs to be assessed; e) Facultative myrmecophily and parasitism of larvae does not endanger the establishment and maintenance of a new population.

a) Translocations do not solve the root problem, habitat degradation:

Translocations were necessary in the case of *P. bavius hungarica*, as most of the extant populations were threatened with extinction, even in areas where their habitat had been placed under governmental protection. Changing the management practices within national conservation areas will take time, time which is not available for many species. Translocations to areas where the protection of the habitat can be ensured for the longer term allow the creation of refugia, where the species can maintain viable populations. Such populations can act as donors in the future.

b) The genetic makeup of the newly-established population is determined by just a few individuals from two source populations:

We assume that this West Asian-Mediterranean species has been subject to permanent local population extinctions, followed by their recovery, both due to natural causes during its expansion (habitat isolation, habitat sensitivity, climate change etc.) and anthropogenic causes (habitat destruction and fragmentation), which may have led to their genetic impoverishment. However, species genetically eroded by isolation and fragmentation, have managed to develop new strategies, being able to restore their populations from an extremely small number of founding individuals (Hewitt 1996; Hanski 1999; Habel et al. 2009, 2016; Schmitt and Varga 2012; Kajtoch et al. 2016).

Subsequently, before the changes caused by human activities (habitat degradation and fragmentation), natural selection may have succeeded in eliminating deleterious alleles from small and isolated populations. As a result of this filtering, small and isolated populations, characterised by a low number of individuals, may not suffer from homozygosity and there is no or very little degenerative inbreeding (Habel et al. 2009). In other words, the reduced genetic diversity

of today's small and isolated populations may not be recent; genetic erosion having taken place before humans destroyed and fragmented natural habitats.

Several studies raise the possibility that high genetic variation in isolated, small populations can be a disadvantage by increasing the extinction vortex (Pecsenye et al. 2014; Habel et al. 2019b). The low genetic differentiation of populations between regions has been emphasised in *Polyommatus ripartii* and *Kretania sephirus* (Pecsenye et al. 2014; Kajtoch et al. 2016), species with similar ecological requirements and post-glacial history such as *P. bavius hungarica*. Therefore, lower genetic diversity in species naturally occurring in small and isolated populations, while certainly carrying risks, should not automatically be considered a disadvantage for colonisation or recolonisation measures (Halford et al. 2024).

c) Introducing species to new environments could have unforeseen consequences for local communities:

We do not expect any potential impact on local communities following the introduction of *P. bavius hungarica*. The butterfly is extremely specialised on the flowers of *S. nutans* and the plant is abundant in the area. There is no other insect species that is monophagous on the same food plant in the area and the species communities from the area selected for translocation are similar to the source habitat of *P. bavius hungarica*. Monitoring of the populations should ensure that any negative impacts are quickly recognised and mitigated where possible.

d) While in the short term, the translocation has been successful, long term survival chances still needs to be assessed:

Long-term survival can never be guaranteed, especially in the face of climate change. The current climate warming favours an area expansion in habitats that 20 to 30 years ago were not optimal for *P. bavius hungarica* from a climatic point of view. However, every effort is being made in monitoring the status of the populations. It will also be interesting to see whether the species will be able to expand its range.

Botanists have often emphasised the biodiversity and ecological peculiarities of the Transylvanian landslide hills (Schneider-Binder 2007; Akeroyd and Page 2011). Large and small slumping hills should be considered as important habitats and potential sources of propagules for plant communities in the surrounding areas (Sutcliffe et al. 2016). The same can be asserted for insects, for which the isolated tumps can be considered as genetic dispersal sources.

e) Facultative myrmecophily and parasitism of larvae does not endanger the establishment and maintenance of a new population:

P. bavius hungarica is currently known to enter facultative myrmecophilous relationships with two ant species: *Crematogaster sordidula* (Nylander, 1849) and *C. atricolor* (Nylander, 1849) (Crișan et al. 2011). Both these species have been recorded in Apold, albeit the density of their nests not being known. Despite this knowledge gap, we do not expect that the establishment of the new population of *P. bavius hungarica* will be limited by the availability of its facultative hosts ants. Although butterflies are hosts for numerous parasitoids, literature does not

cite any species for the genus *Pseudophilotes*, but quite a few for Polyommatinae (Shaw et al. 2009). Due to the lack of data on specific parasitoids, we cannot estimate their effect on the new *P. bavius hungarica* population from Apold.

Management of the translocation site and planned conservation measures

The main location of *P. bavius hungarica* in Apold is owned by the ADEPT Foundation, the coordinator of the "Metamorphosis" project in Romania and numerous other projects for the study, protection and conservation of biodiversity in Transylvania. Together with the ADEPT Foundation, we have elaborated a detailed management plan for the area, with the aim of ensuring the long-term survival of the new population. In contrast to the source sites, the ability to shape the management plan has ensured that appropriate actions can be taken for the survival of this species.

The main management measures aim at controlling intensive grazing and mowing, as well as limiting the impact of vegetation fires. We will, thus, impose a grazing ban on the tumps or, alternatively, restrict grazing from the beginning of April to 15 June. When grazing is prohibited, the vegetation will be mowed every two years or annually after 15 June, with mandatory removal of the mowed plant mass. Measures will be taken to ensure that the dry vegetation does not catch fire, especially in April. We will start with a complete grazing ban, coupled with mowing; however, these management strategies will be adapted, based on the reaction of the *S. nutans* plants. Furthermore, over the next 2 to 3 years, the nucleus of the newly-formed population will be reinforced and genetically replenished with further *P. bavius hungarica* females originating from other populations in Transylvania. The population numbers and status of both *P. bavius hungarica* and *S. nutans* will be monitored annually.

In order to preserve the high biodiversity of the area, its geological structure and the corresponding landscape aspect in the long term, efforts are being made to obtain the status of a nature protected area of local importance, followed by further efforts to obtain the status of a protected area of national interest for the Apold tump complex. The particularly good cooperation with the Municipality of Apold offers great opportunities for the realisation of the aforementioned goals.

Ideally, we will also be able to promote a change in the management strategies at the original locations of *P. bavius hungarica*. Unfortunately, although there are recommendations and suggestions for the habitat management of endangered butterfly species in Europe, their implementation at a national or even local level is poor (Van Swaay et al. 2012). This is, unfortunately, the case for many rare species in Romania. Until in situ conservation measures are adapted to fit the need of the species they are meant to protect, translocation efforts for rare and endangered species may offer a way to ensure the survival of these species.

Conclusion

The conservation of threatened species, in particular of those with narrow niches, low mobility and distribution ranges, poses significant challenges. Here, we

showed that translocation, even outside of a species actual range, can be successful, provided that habitat requirements are met. We thus show how refuge areas for particular species, like *P. bavius hungarica*, can be created, our study potentially serving as an example for further such attempts. However, a detailed evaluation is needed in the choice of species and in the area chosen for translocation. When conducted appropriately, translocations can potentially ensure the longer-term survival of threatened species.

Acknowledgments

All activities related to translocation were carried out in the LIFE project “Developing best practices in butterfly conservation in Central and Eastern Europe” (LIFE21-NAT-SK-LIFE Metamorphosis/101074487).

The authors and the team from the “Metamorphosis” project are grateful to the Natural Monuments Commission of the Romanian Academy, which favourably approved our request to carry out translocations with several vulnerable species of butterflies from Romania.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

This study and report were developed with financial support from the EU-funded LIFE project "Developing best practices in butterfly conservation in Central and Eastern Europe" (LIFE21-NAT-SK-LIFE Metamorphosis/101074487).

Author contributions

Conceptualisation, L.R. and D.R.; methodology, L.R. and A.C.; software, A.C.; validation, R.P., A.C., F.M.P. and D.R.; investigation, R.P., L.R., A.C. and F.M.P.; resources, L.R. and R.P.; data curation, A.C.; writing—original draft preparation, L.R. and D.R.; — review and editing, R.P., L.R., A.C., F.M.P. and D.R; visualisation, A.C. and D.R.; supervision, L.R. and D.R.; project administration, R.P.; funding acquisition, R.P. and L.R. All authors have read and agreed to the published version of the manuscript.

Author ORCIDs

László Rákosy https://orcid.org/0000-0002-7793-6996
Florin-Mihai Pop https://orcid.org/0009-0002-9996-4741
Andrei Crișan https://orcid.org/0000-0003-3501-785X
Demetra Rákosy https://orcid.org/0000-0001-8010-4990

Data availability

All of the data that support the findings of this study are available in the main text.

References

Akeroyd JR, Page N (2011) Conservation of high nature value (HNV) grassland in a farmed landscape in Transylvania, Romania. Contributii Botanice 46: 57–71.

Andersen A, Simcox JD, Thomas AJ, Nash RD (2014) Assessing reintroduction schemes by comparing genetic diversity of reintroduced and source populations: A case study of the globally threatened large blue butterfly (*Maculinea arion*). Biological Conservation 175: 34–41. https://doi.org/10.1016/j.biocon.2014.04.009

Balan DC, Surugiu I, Bulai P, Corduneanu G, Corduneanu C (2020) Observaţii asupra faunei de lepidoptere din situl ROSCI0396 „Dealul Pădurea Murei - Sângeorzu Nou", judeţul Bistriţa-Năsăud. Mnemosyne 11: 5–8.

Bellis J, Longden M, Styles J, Dalrymple S (2021) Using macroecological species distribution models to estimate changes in the suitability of sites for threatened species reintroduction. Ecological Solutions and Evidence 2(1): e12050. https://doi.org/10.1002/2688-8319.12050

Bubac MC, Johnson CA, Fox AJ, Cullingham IC (2019) Conservation translocations and post-release monitoring: Identifying trends in failures, biases, and challenges from around the world. Biological Conservation 238: 108239. https://doi.org/10.1016/j.biocon.2019.108239

Čelik T, Kralj-Fišer S, Šilc U, Küzmič F, Vreš B (2024) Reviving of *Coenonympha oedippus*: A comprehensive approach to the reintroduction of an endangered European butterfly. Insect Conservation and Diversity, 1–16. https://doi.org/10.1111/icad.12778

Costache C, Crișan A, Rakosy L (2021) The decline of butterfly populations due to climate and land use change in Romania. Climate and Land Use Impacts on Natural and Artificial Systems, 1st edn., Mitigation and Adaptation 15: 271–285. https://doi.org/10.1016/B978-0-12-822184-6.00002-8

Crișan A (2012) Assessment of *Pseudophilotes bavius hungarica* ecological niche vulnerability due to land use and climate changes using GIS technics. PhD thesis, "Babeș-Bolyai" University, Cluj-Napoca.

Crișan A, Sitar C, Craioveanu C, Rákosy L (2011) The Protected Transylvanian Blue (*Pseudophilotes bavius hungarica*): New information on the morphology and biology. Nota Lepidopterologica 34(2): 163–168.

Crișan A, Sitar C, Craioveanu MC, Vizauer T-C, Rákosy L (2014) Multiannual population size estimates and mobility of the endemic *Pseudophilotes bavius hungarica* (Lepidoptera: Lycaenidae) from Transylvania (Romania). North-Western Journal of Zoology 10(Supplement 1): S115–S124.

Crișan A, Vizauer T-C, Rákosy L (2023) The protected species *Pseudophilotes bavius hungarica* (Diószeghy, 1913): oviposition strategy, new records and conservation (Lepidoptera: Lycaenidae). SHILAP Revista de Lepidopterologia 51(204): 709–719. https://doi.org/10.57065/shilap.790

Devictor V, van Swaay C, Brereton T, Brotons L, Chamberlain D, Heliölä J, Herrando S, Julliard R, Kuussaari M, Lindström A, Reif J, Roy BD, Schweiger O, Settele J, Stefanescu C, Van Strien A, Van Turnhout C, Vermouzek Z, DeVries WM, Wynhoff I, Jiguet F (2012) Differences in the climatic debts of birds and butterflies at a continental scale. Nature Climate Change 2(2): 121–124. https://doi.org/10.1038/nclimate1347

Diamond ES, Frame MA, Martin AR, Buckley BL (2011) Species' traits predict phenological responses to climate change in butterflies. Ecology 92(5): 1005–1012. https://doi.org/10.1890/10-1594.1

Dincă V, Cuvelier S, Mølgaard MS (2011) Distribution and conservation status of *Pseudophilotes bavius* (Lepidoptera: Lycaenidae) in Dobrogea (south-eastern Romania). Phegea 39(2): 59–67.

Draper D, Marques I, Iriondo MJ (2019) Species distribution models with field validation, a key approach for successful selection of receptor sites in conservation translocations. Global Ecology and Conservation 19: e00653. https://doi.org/10.1016/j.gecco.2019.e00653

Ellis S, Bourn N, Bulman C (2011) Landscape-scale conservation for butterflies and moths: lessons from the UK. Butterfly Conservation, Wareham, Dorset. https://doi.org/10.1007/978-94-007-1442-7_27

Fărcaș S, Popescu F, Tanțău I (2006) Distribuția spațială și temporară a stejarului, frasinului și carpenului în timpul Tardi-și Postglaciarului, pe teritoriul României. Presa Universitară Clujeană, 214 pp.

Forister ML, Pelton EM, Black SH (2019) Declines in insect abundance and diversity: We know enough to act now. Conservation Science and Practice 1: e80. https://doi.org/10.1111/csp2.80

Habel JC, Zachos FE, Finger A, Meyer M, Louy D, Assmann T, Schmitt T (2009) Unprecedented long-term genetic monomorphism in an endangered relict butterfly species. Conservation Genetics 10: 1659–1665. https://doi.org/10.1007/s10592-008-9744-5

Habel JC, Engler JO, Rödder D, Schmitt T (2012) Contrasting genetic and morphologic responses on recent population decline in two burnet moths (Lepidoptera, Zygaenidae). Conservation Genetics 13(5): 1293–1304. https://doi.org/10.1007/s10592-012-0372-8

Habel JC, Segerer A, Ulrich W, Torchyk O, Weisser WW, Schmitt T (2016) Butterfly community shifts over two centuries. Conservation Biology 30(4): 754–762. https://doi.org/10.1111/cobi.12656

Habel JC, Samways MJ, Schmitt T (2019a) Mitigating the precipitous decline of terrestrial European insects: Requirements for a new strategy. Biodiversity and Conservation 28(6): 1343–1360. https://doi.org/10.1007/s10531-019-01741-8

Habel JC, Trusch R, Schmitt T, Ochse M, Ulrich W (2019b) Long-term large-scale decline in relative abundances of butterfly and burnet moth species across south-western Germany. Scientific Reports 9(1): 14921. https://doi.org/10.1038/s41598-019-51424-1

Halford G, Bulman CR, Bourn NAD, Maes D, Harpke A, Hodgeson JA (2024) Can species distribution models using remotely sensed variables inform reintroductions? Trialling methods with *Carterocephalus palaemon* the Chequered Skipper Butterfly. Journal of Insect Conservation 28: 909–921. https://doi.org/10.1007/s10841-024-00555-6

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans W, Müller A, Sumser H, Hörren T, Goulson D, de Kroon H (2017) More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE 12(10): e0185809. https://doi.org/10.1371/journal.pone.0185809

Hallmann CA, Ssymank A, Sorg M, de Kroon H, Jongejans E (2021) Insect biomass decline scaled to species diversity: General patterns derived from a hoverfly community. Proceedings of the National Academy of Sciences of the United States of America 118(2): e2002554117. https://doi.org/10.1073/pnas.2002554117

Halsch CA, Shapiro AM, Fordyce JA, Nice CC, Thorne JH, Waetjen DP, Forister ML (2021) Insects and recent climate change. Proceedings of the National Academy of Sciences of the United States of America 118(2): 1–9. https://doi.org/10.1073/pnas.2002543117

Hanski I (1999) Metapopulation Ecology. Oxford Series in Ecology and Evolution. Oxford University Press, Oxford, England, 324 pp. https://doi.org/10.1093/oso/9780198540663.001.0001

Herrando S, Titeux N, Brotons L, Anton M, Ubach A, Villero D, García-Barros E, Munguira ML, Godinho C, Stefanescu C (2019) Contrasting impacts of precipitation on Mediterranean birds and butterflies. Scientific Reports 9(1): 5680. https://doi.org/10.1038/s41598-019-42171-4

Hewitt GM (1996) Some Genetic Consequences of Ice Ages, and Their Role in Divergence and Speciation. Biological Journal of the Linnean Society. Linnean Society of London 58(3): 247–276. https://doi.org/10.1006/bijl.1996.0035

Hunter-Ayad J, Ohlemüller R, Rodríguez Recio M, Seddon PJ (2020) Reintroduction modelling: A guide to choosing and combining models for species reintroductions. Journal of Applied Ecology 57(7): 233–1243. https://doi.org/10.1111/1365-2664.13629

Joyce DA, Pullin AS (2003) Conservation implications of the distribution of genetic diversity at different scales: A case study using the marsh fritillary butterfly (*Euphydryas aurinia*). Biological Conservation 114(3): 453–461. https://doi.org/10.1016/S0006-3207(03)00087-9

Jutzeler D, Rákosy L, Bros E (1997) Observation et élevage de *Pseudophilotes bavius* (Eversmann, 1832) des environs de Cluj; distribution de cette espèce en Roumanie. Une nouvelle plante nouricière de *Colias alfacariensis* (Ribbe, 1905). Bulletin de la Societe Entomologique de Mulhouse (Avril-juin): 23–30.

Kajtoch Ł, Cieślak E, Varga Z, Paul W, Mazur MA, Sramkó G, Kubisz D (2016) Phylogeographic patterns of steppe species in Eastern Central Europe: A review and the implications for conservation. Biodiversity and Conservation 25(12): 2309–2339. https://doi.org/10.1007/s10531-016-1065-2

König F (1992) Morphologische, biologische une ökologische Daten über *Philotes bavius hungarica* Dioszeghy 1913. Lepidoptera. Lycaenidae. Entomologische Zeitschrift 102(9-10): 168-172, 188-191.

Maes D, Verovnik R, Wiemers M, Brosens D, Beshkov S, Bonelli S, Buszko J, Cantú-Salazar L, Cassar L-F, Collins S, Dincă V, Djuric M, Dušej G, Elven H, Franeta F, Garcia-Pereira P, Geryak Y, Goffart P, Gór Á, Hiermann U, Höttinger H, Huemer P, Jakšić P, John E, Kalivoda H, Kati V, Kirkland P, Komac B, Kőrösi Á, Kulak A, Kuussaari M, L'Hoste L, Lelo S, Mestdagh X, Micevski N, Mihoci I, Mihut S, Monasterio-León Y, Morgun DV, Munguira ML, Murray T, Nielsen PS, Ólafsson E, Õunap E, Pamperis LN, Pavlíčko A, Pettersson LB, Popov S, Popović M, Pöyry J, Prentice M, Reyserhove L, Ryrholm N, Šašić M, Savenkov N, Settele J, Sielezniew M, Sinev S, Stefanescu C, Švitra G, Tammaru T, Tiitsaar A, Tzirkalli E, Tzortzakaki O, van Swaay CA, Viborg AL, Wynhoff I, Zografou K, Warren MS (2019) Integrating National Red Lists for prioritising conservation actions for European butterflies. Journal of Insect Conservation 23(2): 301–330. https://doi.org/10.1007/s10841-019-00127-z

McCain CM, Garfinkel CF (2021) Climate change and elevational range shifts in insects. Current Opinion in Insect Science 47: 111–118. https://doi.org/10.1016/j.cois.2021.06.003

Merckx T, Huertas B, Basset Y, Thomas JA (2013) A global perspective on conserving butterflies and moths and their habitats. In: Macdonald WD, Willis JK (Eds) Key Topics in Conservation Biology 2 3(14): 237-257. https://doi.org/10.1002/9781118520178.ch14

Mihuț S, Groza G, Mătase D, Tăut M (2001) Rezervațiile de la Suatu. Inspectoratul de Protecție a Mediului Cluj, Cluj-Napoca.

Mora A, Wilby A, Menéndez R (2023) South European mountain butterflies at a high risk from land abandonment and amplified effects of climate change. Insect Conservation and Diversity 16(6): 838–852. https://doi.org/10.1111/icad.12676

Morariu T, Diaconeasa B, Gârbacea V (1964) Age of land-slidings in the Transylvanian Tableland. Revue Roumaine de Géologie, Géophysique et Géographie, série Géographie 8: 149–157.

Német E, Czekes Z, Markó B, Rákosy L (2016) Host plant preference in the protected myrmecophilous Transylvanian Blue (*Pseudophilotes bavius hungarica*) butterfly (Lepidoptera: Lycaenidae) and its relationship with potential ant partners. Journal of Insect Conservation 20: 765–772. https://doi.org/10.1007/s10841-016-9907-5

Oroian S, Sămărghiţan M, Tănase C (2017) Plants species of community interest identified in the flora of the Transylvanian Plain (Mureş County). Studia Universitatis "Vasile Goldiş". Seria Ştiinţele Vieţii 27(3): 209–214.

Osborne PE, Seddon PJ (2012) Selecting suitable habitats for re-introductions: Variation, change, and the role of species distribution modelling. In: Ewen JG, Armstrong DP, Parker KA, Seddon PJ (Eds) Reintroduction biology: Integrating science and management. Wiley-Blackwell, 73–104. https://doi.org/10.1002/9781444355833.ch3

Pecsenye K, Rácz R, Bereczki J, Bátori E, Varga Z (2014) Loss of genetic variation in declining populations of *Aricia artaxerxes* in northern Hungary. Journal of Insect Conservation 18(2): 233–243. https://doi.org/10.1007/s10841-014-9634-8

Rákosy L (2011) Originea si geneza landschaftului natural-cultural din Transilvania. In: Rákosy L, Momeu L (Eds) Volum comemorativ "Bogdan Stugren". Presa Univ. Clujeană, 27–38.

Rákosy L, Weidlich M (2017) *Rubrapterus bavius* from north-eastern Bulgaria and new data on its conservation status in Romania. Entomologica Romanica 21: 15–22. https://doi.org/10.24193/entomolrom.21.3

Rákosy L, Corduneanu C, Crișan A, Dincă V, Kovács S, Stănescu M, Székely L (2021) Lista roșie a fluturilor din România / Romanian Red List of Lepidoptera. Presa Universitară Clujeană, Cluj-Napoca, 187 pp.

Schmitt T, Varga Z (2012) Extra-Mediterranean refugia: The rule and not the exception? Frontiers in Zoology 9(1): 22. https://doi.org/10.1186/1742-9994-9-22

Schneider E (1996) Refiefbedingte Abfolge von Pflanzengesellschaften an Rutschungshügeln in Siebenbürgen (Harbachhochland). Staphia 45: 83–93.

Schneider-Binder E (2007) Xerophilous and Xero-Mesophilous grasslands on slumping hills around the Saxon villages Apold and Saschiz (Transylvania, Romania). Transylvanian Review of Systematical and Ecological Research 4: 55–64.

Seibold S, Gossner MM, Simons NK, Blüthgen N, Müller J, Ambarlı D, Ammer C, Bauhus J, Fischer M, Habel JC, Linsenmair KE, Nauss T, Penone C, Prati D, Schall P, Schulze E-D, Vogt J, Wöllauer S, Weisser WW (2019) Arthropod decline in grasslands and forests is associated with landscape-level drivers. Nature 574(7780): 671–674. https://doi.org/10.1038/s41586-019-1684-3

Settele J, Kudrna O, Harpke A, Kühn I, Van Swaay C, Verovnik R, Warren M, Wiemers M, Hanspach J, Hickler T, Kühn E, Van Halder I, Veling K, Vliegenthart A, Wynhoff I, Schweiger O (2008) Climatic risk atlas of European butterflies. BioRisk 1: 1–712. https://doi.org/10.3897/biorisk.1

Shaw M, Stefanescu C, Van Nouhuys S (2009) Parasitoids of European butterflies. In: Settele J, et al. (Eds) Ecology of Butterflies in Europe. Cambridge University Press, 130–156.

Sutcliffe LM, Germany M, Becker U, Becker T (2016) How does size and isolation affect patches of steppe-like vegetation on slumping hills in Transylvania, Romania? Biodiversity and Conservation 25(12): 2275–2288. https://doi.org/10.1007/s10531-016-1108-8

Tanțău I (2006) Histoire de la vegetation tardiglaciare et holocène dans les Carpates Orientales (Roumanie). Presa Universitară Clujeană, Cluj-Napoca.

Thomas JA, Bourn NA, Clarke RT, Stewart KE, Simcox DJ, Pearman GS, Curtis R, Goodger B (2001) The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. Proceedings of the Royal Society of London. Series B, Biological Sciences 268(1478): 1791–1796. https://doi.org/10.1098/rspb.2001.1693

Thomas JA, Simcox DJ, Clarke RT (2009) Successful conservation of a threatened *Maculinea* butterfly. Science 325(5936): 80–83. https://doi.org/10.1126/science.1175726

Thomas JA, Simcox JD, Bourn DAN (2011) The restoration of the large blue butterfly to the UK. In: Soorae PS (Ed.) Global Re-introduction Perspectives: 2011. More case studies from around the globe. IUCN/SSC Reintroduction Specialist Group, Gland, Switzerland, and Environment Agency, Abu Dhabi, United Arab Emirates, 189–193.

Van Dyck H, Van Strien AJ, Maes D, Van Swaay CAM (2009) Declines in common, widespread butterflies in a landscape under intense human use. Conservation Biology 23(4): 957–965. https://doi.org/10.1111/j.1523-1739.2009.01175.x

Van Klink R, Bowler DE, Gongalsky KB, Swengel AB, Gentile A, Chase JM (2020) Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. Science 368(6489): 417–420. https://doi.org/10.1126/science.aax9931

Van Klink R, Bowler DE, Gongalsky KB, Shen M, Swengel SR, Chase JM (2024) Disproportionate declines of formerly abundant species underlie insect loss. Nature 628: 359–364. https://doi.org/10.1038/s41586-023-06861-4

Van Swaay CAM, Warren MS (2006) Prime Butterfly Areas of Europe: An initial selection of priority sites for conservation. Journal of Insect Conservation 10(1): 5–11. https://doi.org/10.1007/s10841-005-7548-1

Van Swaay CA, Warren MS (2012) Developing butterflies as indicators in Europe: current situation and future options. De Vlinderstichting/Dutch Butterfly Conservation, Butterfly Conservation UK, Butterfly Conservation Europe, Wageningen, Report number VS2012, 12.

Van Swaay CA, Nowicki P, Settele J, van Strien AJ (2008) Butterfly monitoring in Europe: Methods, applications and perspectives. Biodiversity and Conservation 17(14): 3455–3469. https://doi.org/10.1007/s10531-008-9491-4

Van Swaay C, Cuttelod A, Collins S, Maes D, López Munguira ML, Šašić M, Settele J, Verovnik R, Verstrael T, Warren M, Wiemers M, Wynhoff I (2010) European Red List of Butterflies. Publications Office of the European Union, Luxembourg, 47 pp.

Van Swaay C, Collins S, Dusej G, Maes D, Munguira ML, Rakosy L, Ryrholm N, Šašić M, Settele J, Thomas JA, Verovnik R, Verstrael T, Warren M, Wiemers M, Wynhoff I (2012) Dos and Don'ts for butterflies of the Habitats Directive of the European Union. Nature Conservation 1: 73–153. https://doi.org/10.3897/natureconservation.1.2786

Villero D, Pla M, Camps D, Ruiz-Olmo J, Brotons L (2017) Integrating species distribution modelling into decision-making to inform conservation actions. Biodiversity and Conservation 26(2): 251–271. https://doi.org/10.1007/s10531-016-1243-2

Wagner DL (2012) Moth decline in the Northeastern United States. News of the Lepidopterists' Society 54: 52–56.

Wagner DL (2020) Insect Declines in the Anthropocene. Annual Review of Entomology 65(1): 457–480. https://doi.org/10.1146/annurev-ento-011019-025151

Wagner LD, Eliza M, Grames ME, Forister LM, Berenbaum RM, Stopak D (2021) Insect decline in the Anthropocene: Death by a thousand cuts. Proceedings of the National

Academy of Sciences of the United States of America 118(2): 1–10. https://doi.org/10.1073/pnas.2023989118

Warren MS, Bourn NAD (2011) Ten challenges for 2010 and beyond to conserve Lepidoptera in Europe. Journal of Insect Conservation 15(1–2): 321–326. https://doi.org/10.1007/s10841-010-9356-5

Warren MS, Maes D, van Swaay CA, Goffart P, Van Dyck H, Bourn NA, Wynhoff I, Hoare D, Ellis S (2021) The decline of butterflies in Europe: Problems, significance, and possible solutions. Proceedings of the National Academy of Sciences of the United States of America 118: e2002551117. https://doi.org/10.1073/pnas.2002551117

Wildman JP (2023) The history, ecology, and reintroduction of the chequered skipper butterfly *Carterocephalus palaemon* in England. Unpublished PhD University of Northampton, Northampton, England.